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U1S S1233

(56) Documents Cited
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US 4615071 A

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(54) Abstract Title
**Robotic vacuum cleaner with overload protection clutch**

(57) A selfdriven robotic vacuum cleaner has independently driven wheels 14 coupled to a drive motor 22 via gearing 23, 25 which incorporates an overload protection device, eg a slip clutch, 26 that slips when excessive external rotational forces are applied to the drive wheels 14. The slip clutch 26 comprises balls 27 which are urged in a radial direction by springs 28 so as to engage in detents 29 in the gear 25. When an excessive force is applied to the drive wheels the balls 27 ride out of the detents 29 and roll over a smooth cylindrical inner surface 25A of gear 25. The slip clutch 26 is situated coaxially and within the drive wheel 14 to provide a compact assembly which occupies minimal space. Wheel 14 is moulded, eg from ABS plastics, and has a hub 19 which houses a pair of bearings 20 supported on a shaft 21 which is mounted on chassis 12 of the cleaner.

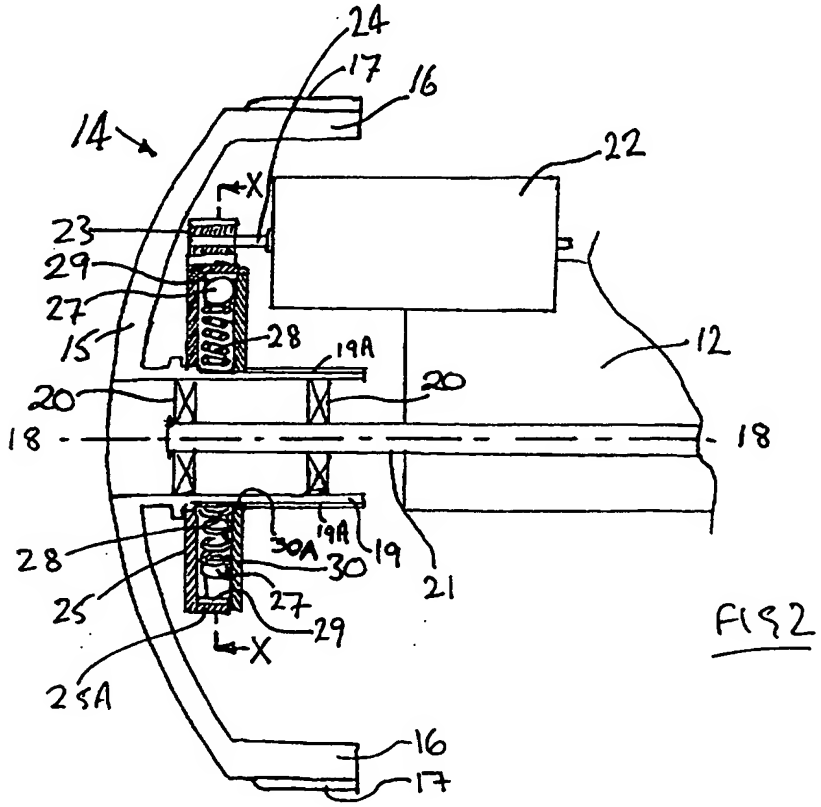


Fig 2

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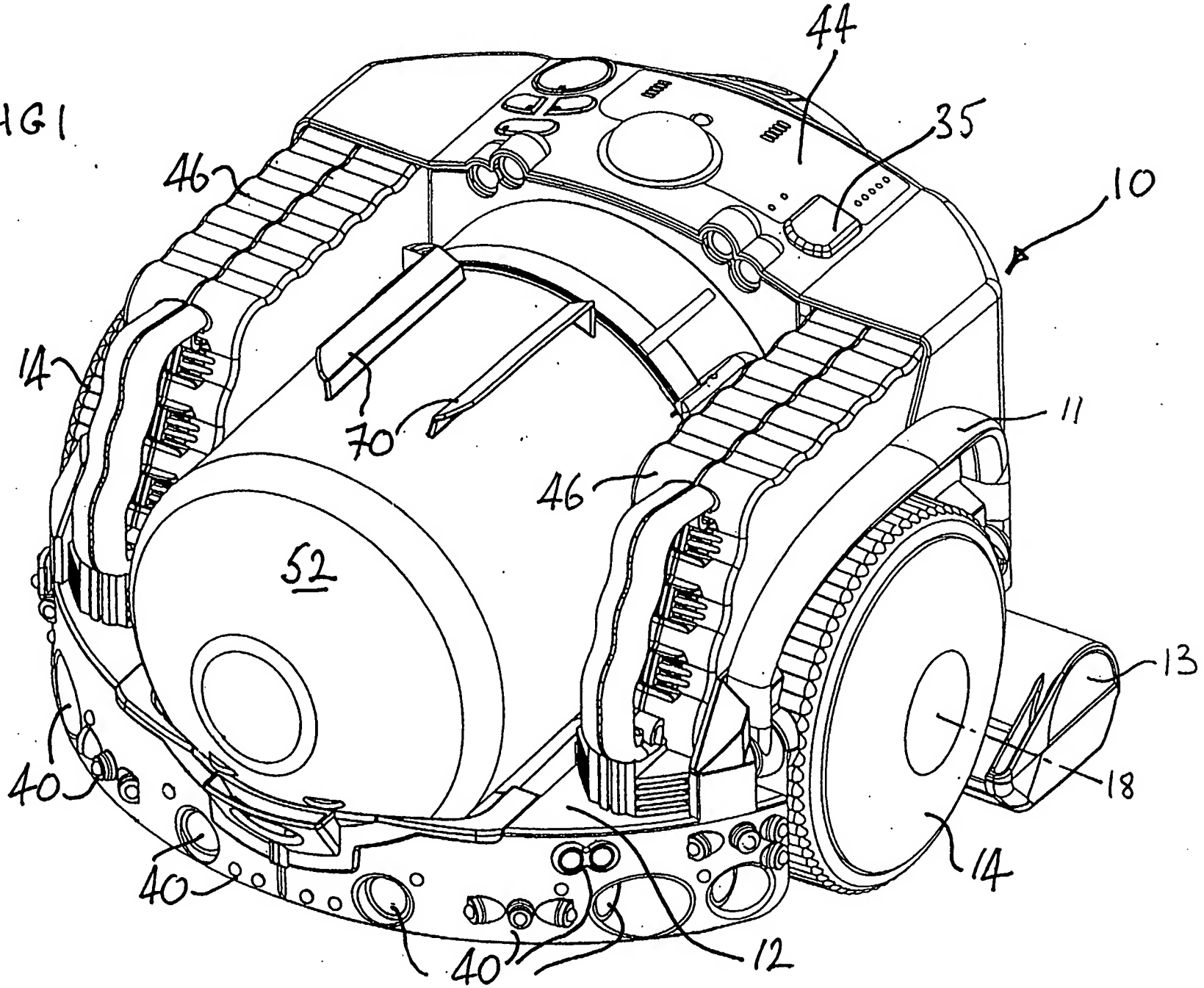
FIG 1



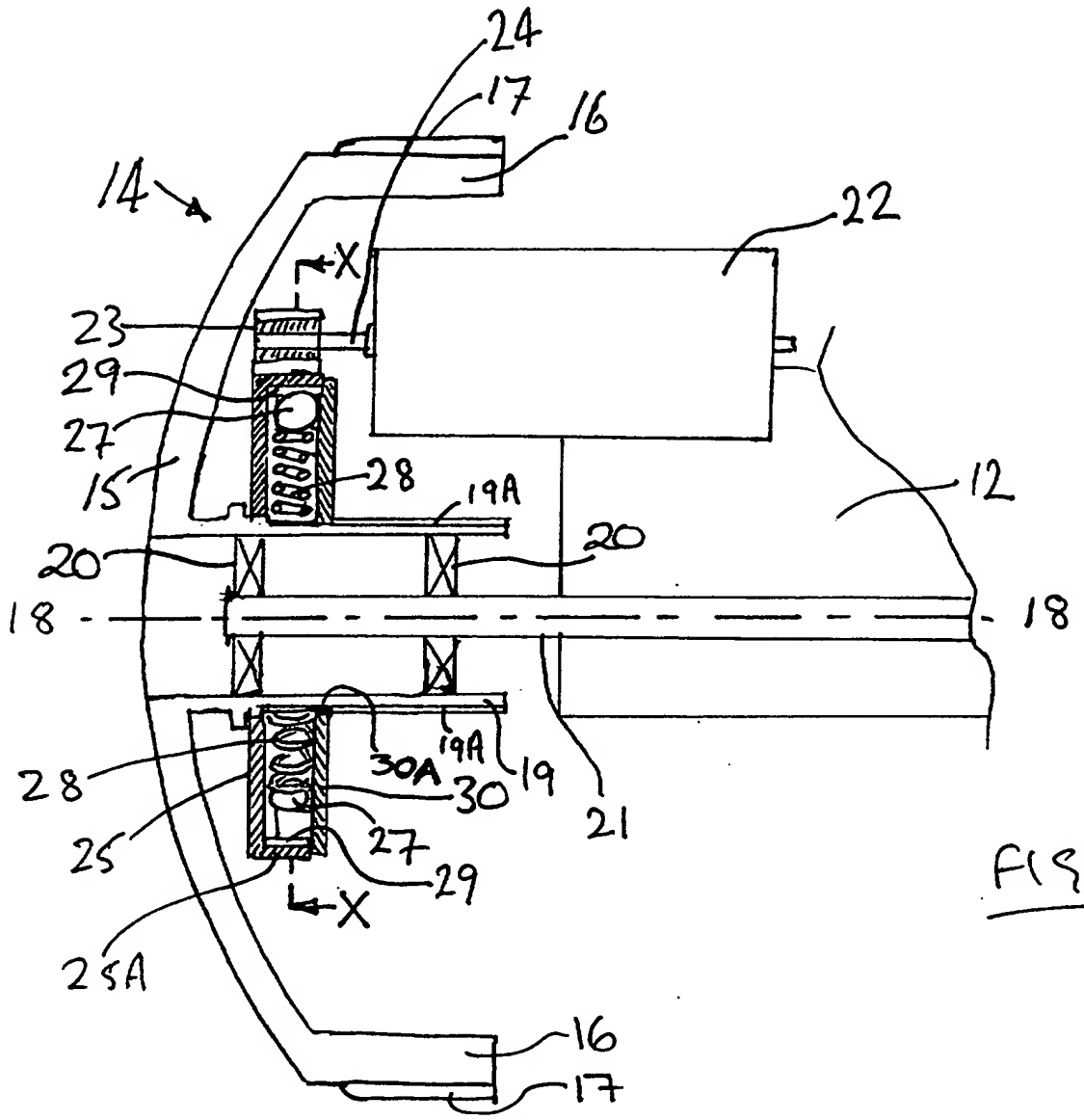

24
17
16
14
22
X
23
29
27
15
28
19A
12
20
20
18
18
28
30A
19A
19
30
21
25
27
29
X
25A
16
17

FIG 2

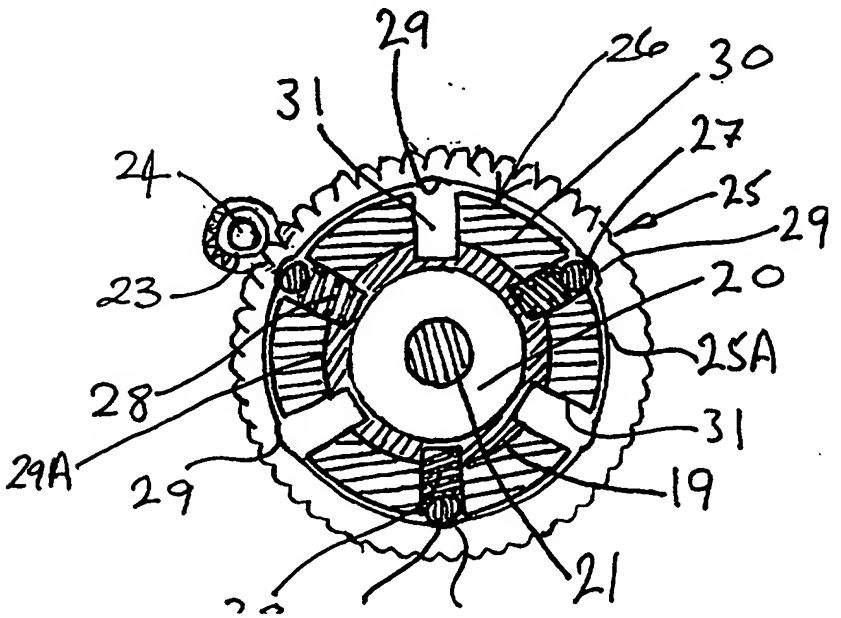

29
26
30
31
27
24
25
29
23
20
25A
28
31
29A
29
19
21

FIG 3

# Mobile Device

This invention relates to a self-driven mobile device, particularly but not exclusively to a robotic floor cleaning device such as a vacuum cleaner.

A self-guiding vacuum cleaner is known from for example EP 0 803 224 A. This self-guiding vacuum cleaner includes a chassis which supports a housing with a cover and a front part which is moveable with respect to the chassis. The chassis supports a brush nozzle and roll, a fan unit, a dust container, rechargeable batteries, a drive motor for driving each of the two wheels, and another motor for driving the brush roller. The cleaner has a navigation system provided with electronic circuits and electric components necessary to guide and control movement of the vacuum cleaner on the floor.

In a robotic vacuum cleaner the wheels are driven forwards in the same direction for forward motion, backwards for backwards motion and in opposite directions to turn the vacuum cleaner about a central axis. Such a device can suffer misuse or maltreatment for example by small children using it as a play thing. Also, if an autonomous vacuum cleaner is to be used in an alternative, manual mode with a hose connected to it, then once again there is a possibility of undue force being applied through the hose if for example the device becomes caught or wedged against furniture or other obstacles.

Under the circumstances just described there is the possibility of external rotational forces being applied to the drive wheels during automatic operation of the device, when switched off or in manual mode, and it is an object of the present invention to minimize or eliminate damage to the wheels and drive mechanism from such externally-originating forces.

According to the present invention there is provided a robotic mobile device having at least one drive wheel driven by a motor, and a rotational drive mechanism coupling the

motor and the wheel, said coupling comprising a clutch which will slip when a torque applied externally to the wheel exceeds a preset limit.

Preferably the mechanism comprises a toothed wheel mounted for coaxial rotation on the driven wheel, and the clutch is coupled between the toothed wheel and the driven wheel.

Preferably also the clutch comprises a radially-biased plunger and a cooperating detent. Preferably the drive wheel is hollow and the clutch is situated within the drive wheel. Preferably the drive mechanism is situated within the drive wheel.

In order that the invention may be more clearly understood reference will now be made to the accompanying drawings, in which:-

Figure 1 is a perspective view of a robotic vacuum cleaner embodying the invention;

Figure 2 is a section through a wheel and drive mechanism along the axis 18 of the cleaner of Figure 1; and

Figure 3 is a section through the drive mechanism on the line X-X of Figure 2.

Referring to Figure 1 of the drawings, there is shown a robotic vacuum cleaner 10 having a supporting chassis 12 which is generally circular in plan view and is supported on two driven wheels 14 and a rearwardly positioned castor wheel (not shown). The chassis 12 provides support for the components of the cleaner 10. The driven wheels 14 are arranged at either end of a diameter of the chassis 12 lying along the axis 18, the axis 18 also being the rotational axis of the wheels 14. This axis 18 lies perpendicular to the longitudinal axis of the cleaner 10. The driven wheels 14 are mounted independently of one another and are each driven by a motor 22 (Figure 2) which is capable of driving the respective wheel 14 in either a forward direction or a reverse

direction. By driving both wheels 14 forward at the same speed, the cleaner 10 can be driven in a forward direction. By driving both wheels 14 in a reverse direction at the same speed, the cleaner 10 can be driven backwards. By driving the wheels 14 in opposite directions, the cleaner 10 can be made to rotate about its own central axis so as to effect a turning manoeuvre. Other turning manoeuvres can be effected by driving one wheel alone or by driving both wheels at different speeds. The aforementioned method of driving a vehicle is well-known and will not be described further here.

The chassis 12 carries a plurality of movement control sensors 40 which are designed and arranged to detect obstacles in the path of the cleaner 10 and its proximity to, for example, a wall or other boundary to the area to be cleaned, such as a piece of furniture. The sensors 40 comprise several ultrasonic sensors and several infrared sensors. The array illustrated in Figure 1 is not intended to be limitative and the arrangement of the sensors 40 does not form part of the present invention. Suffice it to say that the vacuum cleaner 10 carries sufficient sensors 40 to enable the cleaner 10, through associated electronic circuitry within the cleaner, to guide itself or to be guided around a predefined area so that the said area can be cleaned. Control software, comprising navigation controls and steering devices, is housed within the cleaner 10 beneath the control panel 44. Battery packs 46 are mounted on the chassis 12 inwardly of the driven wheels 14 to provide power to the motors 22 for driving the wheels 14, a brush roller (not shown) mounted within a floor cleaning head 13, and the control software. The battery packs 46 are removable to allow them to be transferred to a battery charger (not shown). The floor cleaning head 13 has a suction opening (not shown) facing the surface on which the cleaner 10 is supported. The suction opening extends across the majority of the width of the cleaner head 13.

Dirt separation is achieved by means of a cyclonic separator 52 mounted on the chassis 10 and a suction fan housed within the cleaner 10 beneath the control panel 44. An air transfer conduit (not shown) extends between the cleaner head 13 and the separator 52.

The separator 52, can be removed from the cleaner 10 for emptying purposes and lifted by means of the integrally moulded handles 70.

The vacuum cleaner 10 described above has a diameter of around 45cms and weighs about 9 kilogrames. It has a handle 11 by means of which it can be lifted from the floor, carried to a new location, and lowered on to the next floor surface to be cleaned.

The vacuum cleaner 10 described above operates in the following manner. In order for the cleaner 10 to traverse the area to be cleaned, the wheels 14 are driven by their respective motors 22 which in turn are powered by the batteries 46. The direction of movement of the cleaner 10 is determined by the control software which communicates with the sensors 40. The sensors 40 are designed to detect any obstacles in the path of the cleaner 10 so as to navigate the cleaner 10 around the area to be cleaned. Methodologies and control systems for navigating a robotic vacuum cleaner around a room or other area are well documented elsewhere and do not form part of the inventive concept of this invention.

The wheel 14 and associated drive mechanism are shown more clearly in Figures 2 and 3. Referring to these Figures, the wheel 14 is moulded from ABS plastics or the like and has a curved, substantially part-spherical wall portion 15 and an integral cylindrical portion 16 carrying an over-moulded tyre 17 which is ribbed in a direction parallel to the axis of rotation 18. The ribs are clearly visible in Figure 1. The wheel 14 has a hub 19 which houses a pair of bearings 20 supported on a shaft 21 which is mounted in the chassis 12 of the cleaner 10.

The wheel 14 is driven by the drive motor 22 via a rotary drive mechanism. The mechanism comprises a pinion 23 mounted on a shaft 24 of the motor 22, a hollow toothed wheel 25 mounted for rotation on the hub 19 of the wheel, and an overload-protection clutch 26 located between the hub 19 and the toothed wheel 25. The clutch comprises a cage 30 having a plurality of radially extending recesses 31 and a plurality

of balls 27, one ball 27 being located in and freely movable along each recess 31. Each ball 27 is biased in a radially outward direction towards the toothed wheel 25 by a compression spring 28 which is seated at the radially innermost end of the respective recess 31 and which rests against the respective ball 27. The balls 27 are thus pressed towards and into a plurality of hemispherical or semi-cylindrical detents 29 formed in the radially innermost face 25A of the toothed wheel 25.

The wheel hub 19 is splined at 19A on its outer surface so as to mate with corresponding splines 30A on the radially inner surface of the cage 30 so that the cage 30 is rotationally locked to the wheel hub 19. Other methods of fixing the cage 30 to the wheel hub 19 will be equally appropriate and employable.

The balls 27 are radially biased outwardly into the respective detents 29. When the motor 22 is energized it will drive the toothed wheel 25 via the pinion 23 attached to the shaft 24. The wheel 25 is rotationally locked to the cage 30 as long as the balls 27 remain seated in their respective detents 29. The cage 30 is rotationally locked to the wheel hub 19 by the inter-engaging splines 19A on the hub 19 and 30A on the cage 30, and so the wheel 14 is driven by the motor 22. The detents 29 are symmetrical in shape so that the balls 27 remain seated therein in either direction of rotation of the drive motor 22.

If an excessive external rotational force is applied in either direction to the wheel 14, to the extent that the force exceeds a preset torque, then the balls 27 will be forced to move against the biasing force of the springs 28 in a radially inward direction. The balls 27 then ride up out of their detents 29 and will roll over the smooth cylindrical inner surface of the portion 25A of the toothed wheel 25 which extends between the detents 29, until the balls 27 engage in the adjacent detent 29. If the torque is still sufficiently high, the balls 27 will again become unseated and so the clutch 26 will continue to slip for so long as the torque exceeds the preset limit. In this event, the excessive torque applied to the wheel 14 is absorbed within the clutch 26 and is not passed to the motor

22. The motor 22 is thus protected. When the torque drops below the preset limit again, the wheel 14 and the motor become reconnected.

In the present embodiment there are shown three balls 27. The preset torque limit could be increased either by increasing the number of balls and springs (there are three vacant recesses 31 shown making a total availability of 6 balls and springs) or by providing firmer springs, or by a combination of these two factors. Likewise the preset torque can be reduced by reducing the number of balls and springs or by providing weaker springs or by a combination of the two factors.

Additionally it will be clear that the depth of the detents will also have a significant effect on the torque at which slip takes place. In the present embodiment the detents 29 are hemispherical or semi-cylindrical recesses having the same radius as the balls and having a depth of about 60% of the ball radius. By increasing the depth the preset torque will be increased and, correspondingly, by reducing the depth the preset torque will be decreased. The preset torque in the present embodiment lies in the range 0.5 to 1.5 Nm in order to protect the toothed wheel and pinion of the rotational drive mechanism.

The reduction ratio in the rotational drive mechanism is 18:1 and the drive motor is a conventional DC commutator motor. Many of the parts described are moulded from ABS plastics material. The motor shaft 24, the balls 27, the springs 28 and the drive wheel shafts 21 and bearings 20 are advantageously made of metal. The toothed wheel 25 may be made from a material such as Acetal.

The rotational drive mechanism is the same for both wheels 14 of the vacuum cleaner 10 shown in Figure 1. In particular it can be seen that the rotational drive mechanism is completely housed within the hollow drive wheel 14. Furthermore the overload protection clutch 26, by using radially biased balls 27, occupies very little space. The overload protection clutch 26 in each wheel 14 minimizes the possibility of damage to

the rotational drive mechanism and the motor 22 should undue rotational external forces be applied to the wheels 14. It is to be noted that the preset torque for the overload protection clutch 26 is higher than the torque produced by the drive motor 22 in normal use of the vacuum cleaner 10. Should the vacuum cleaner 10 become jammed or blocked during use, then the onboard electronic circuitry will sense that fact and switch off the drive current to the motors 22. It is not intended that the overload protection clutch 26 described herein will operate, i.e. slip, during normal use of the vacuum cleaner.

Variations and modifications to the embodiment described above will be apparent to a skilled reader. For example, the balls 27 can be replaced by any alternative type of plunger which can be moved into and out of the respective detent. It will be appreciated that the ball and spring arrangement shown in the embodiment could be replaced by a single, compressible unit.

## CLAIMS

1. A self-driven mobile device having at least one drive wheel drivable by a motor, and a rotational drive mechanism coupling the motor and the drive wheel, said rotational drive mechanism comprising a clutch mechanism which is adapted to cause the motor to slip with respect to the drive wheel when a torque applied externally to the drive wheel exceeds a preset limit.

2. A device as claimed in Claim 1, wherein said rotational drive mechanism comprises a toothed wheel mounted for coaxial rotation on the drive wheel, and the clutch mechanism is coupled between the toothed wheel and the drive wheel.

3. A device as claimed in Claim 1 or Claim 2, wherein the clutch mechanism comprises at least one plunger biased radially in respect of the axis of rotation of the clutch mechanism, and at least one cooperating detent for receiving the plunger.

4. A device as claimed in any preceding claim, wherein the drive wheel is hollow and the clutch mechanism is situated within the drive wheel.

5. A device as claimed in Claim 4, wherein the rotational drive mechanism is situated within the drive wheel.

6. A device as claimed in any preceding claim, and constituting a vacuum cleaner.

7. A device as claimed in Claim 6, wherein the vacuum cleaner is a robotic vacuum cleaner.

8. A device as claimed in any preceding claim, wherein the torque preset limit is higher than the torque provided at the or each drive wheel by the or each motor.

9. A device as claimed in any preceding claim, wherein two drive wheels are provided, each drive wheel being drivable by a respective motor and each drive wheel having a respective rotational drive mechanism coupling the respective drive wheel and the respective motor, each said rotational drive mechanism comprising a clutch mechanism which is adapted to cause the respective motor to slip with respect to the respective drive wheel when a torque applied externally to the respective drive wheel exceeds a preset limit.

10. A vacuum cleaner substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

INVESTOR IN PE

**Application No:** GB 9917234.8
**Claims searched:** 1 to 10

**Examiner:** Mike Mckinney
**Date of search:** 10 January 2000

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): F2C.

Int Cl (Ed.7): A47L 9/00; F16D 7/10, 43/208.

Other: ONLINE: WPI; EPODOC; JAPIO.

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| X | GB 1472484 | (IDEAL TOY) see figs and lines 30 to 67 page 2. | 1 to 5 and 8. |
| X | GB 1275513 | (ZINCK) see figs and lines 61 to 97 page 4. | 1 to 5 and 8. |
| X | GB 0370977 | (MONTGRAND) see figs and lines 100 to 101 page 1. | 1 to 5 and 8. |
| X | US 4615071 | (FROHBIETER) see figs and lines 55 to 61 col 3. | 1 and 6. |

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